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CRATERING EQUATIONS FOR ZINC ORTHOTITANATE COATED ALUMINUM

Abstract

The final STS-125 servicing mission (SM4) to the Hubble Space Telescope (HST) in May of 2009 saw the return of the 2nd Wide Field Planetary Camera (WFPC2) aboard the shuttle Discovery. This hardware had been in service on HST since it was installed during the SM1 mission in December of 1993 yielding one of the longest low Earth orbit exposure times (15.4 years) of any returned space hardware. The WFPC2 is equipped with a 0.8 x 2.2 m radiator for thermal control of the camera electronics (Figure 1). The space facing surface of the 4.1 mm thick aluminum radiator is coated with Z93 zinc orthotitanate thermal control paint with a nominal thickness of 0.1 – 0.2 mm. Post flight inspections of the radiator panel revealed hundreds of micrometeoroid/orbital debris (MMOD) impact craters ranging in size from less than 300 to nearly 1000 microns in diameter. The Z93 paint exhibited large spall areas around the larger impact sites (Figure 2) and the craters observed in the 6061-T651 aluminum had a different shape than those observed in uncoated aluminum. Typical hypervelocity impact craters in aluminum have raised lips around the impact site. The craters in the HST radiator panel had suppressed crater lips, and in some cases multiple craters were present instead of a single individual crater. Humes and Kinard[1] observed similar behavior after the WFPC1 post flight inspection and assumed the Z93 coating was acting like a bumper in a Whipple shield. Similar paint behavior (spall) was also observed by Bland[2] during post flight inspection of the International Space Station (ISS) S-Band Antenna Structural Assembly (SASA) in 2008. The SASA, with similar Z93 coated aluminum, was inspected after nearly 4 years of exposure on the ISS. The multi-crater phenomena could be a function of the density, composition, or impact obliquity angle of the impacting particle. For instance, a micrometeoroid particle consisting of loosely bound grains of material could be responsible for creating the multiple craters. Samples were obtained from the HST largest craters for examination by electron microscope equipped with x-ray spectrometers to determine impactor source (micrometeoroid or orbital debris).

In an attempt to estimate the MMOD particle diameters that produced these craters, this paper will present equations for spall diameter, crater depth and crater diameter in Z93 coated aluminum. The equations will be based on hypervelocity impact tests of Z93 painted aluminum at the NASA White Sands Test Facility. Equations inputs for velocities beyond the testable regime are expected from hydrocode simulations of Z93 coated aluminum using CTH and ANSYS AUTODYN.

REFERENCES

[1]Humes, D., Kinard, W., "Meteoroid and Debris Impacts on the WF/PC I Radiator", HST Archive System, http://setas-www.larc.nasa.gov/HUBBLE/PRESENTATIONS/hubble_talk_humes_kinard.html

[2]Bland, M., "Boeing Space Station Meteoroid /Orbital Debris Initial Post Flight Inspection Results for the SASA", Boeing International Space Station Program, D684-13003-41, 2008.

Fig. 1: WFPC2 radiator during post flight inspection.

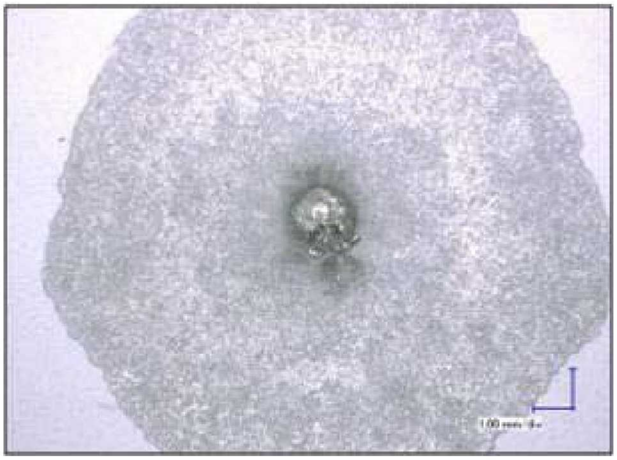

Fig. 2: Impact crater on WFPC2 radiator. Note double crater in center and paint spall . 15 mm spall diameter, 1 mm crater diameter.